would be of high importance to the development of our knowledge.

However the results at which we have arrived may be received, we have only searched for truth. The laws that we have developed as resulting from a geological theory, had revealed themselves long since to our eyes in nature; for during many years we have ever been guided by one single motive—

"Naturâ doceri."

XIX.—*On the Development of Roots, and the Exfoliation of the Cellular Coats of their Extremities.* By Arthur Henfrey, F.R.S.

In the 'Journal of the Royal Agricultural Society of England,' vol. xix. part 2, published in January last, there is an essay on the Structure of Roots, by myself, in the latter part of which is described the mode in which the extremities of roots elongate, and the special arrangements by means of which they are enabled to penetrate the soil. The same subject has more recently been dealt with by MM. Garreau and Brauwers, who appear to have been ignorant of the existence of my paper above referred to; these authors have made some extensive investigations on a further point connected with these root-ends, viz. the possibility that the exfoliated tissue may constitute an excretion capable of exerting an injurious influence upon the same species, and so account for some of the most puzzling phænomena relating to the rotation of crops. As the subject is one of great physiological interest, it may be worth while to extract from the 'Agricultural Journal' those portions of the above-mentioned essay which relate to the anatomy and development of roots, at the same time that I present a translation of the memoir of MM. Garreau and Brauwers. The statements in my own paper are made in somewhat general terms, as it was prepared for a somewhat "popular" class of readers; but they were based upon an original series of investigations which furnished facts in all respects identical with those related in detail by the French authors, to whom, however, exclusively belongs the merit of that part of the inquiry concerning the nature of the substances cast off by the exfoliating radicles.

"The root, as developed in the great majority of plants, presents a highly organized structure, made up of various kinds of true cellular or parenchymatous tissue, together with those kinds of elementary tissue which, under the names of wood-cells, vessels, and ducts, form the hard parts of plants. As a rule, we may divide the internal structures of a root into two regions—

the cortical, and the woody or central region; the former of these is altogether parenchymatous; the latter consists for the most part of woody tissue in natural roots, but contains abundance of parenchyma in plants where the roots become fleshy.

"The *cortical* region is continuous with the rind-structure of the stem, and in young roots consists of a thin layer of squarish parenchymatous cells, more or less densely filled with mucilaginous contents, but completely covered in on the outer surface by a layer of cells firmly connected side by side, forming a kind of skin, called the *epidermis*. This skin is distinguished from that clothing the leaves and young shoots, in accordance with the difference of function, by the absence of the peculiar breathing pores or *stomata*, by which the internal structures of the leaves, &c., are placed in direct communication with the atmosphere. There are no openings of any kind through the skin covering the surface of roots; and the notion formerly entertained of the existence of sponge-like regions at the extremities of roots was an error arising out of imperfect observation, as will appear presently. The cortical region exhibits some striking differences in its subsequent history in different plants. In most cases, especially in the roots of Dicotyledons, and in the branching roots of Monocotyledons, many of the epidermal cells, at a little distance from the growing point of the root or rootlet, grow out into filaments or hair-like processes, constituting the '*fibrils*' of roots. These are mostly invisible to the naked eye; and their presence is chiefly betrayed by the adhesion of the soil to them. When young roots are carefully washed and placed under a magnifying glass, these fibrils are seen very clearly; and on such roots as those of barley, for instance, they exist in enormous numbers.

"At the growing points of roots, the epidermis passes insensibly into the mass of nascent or *cambial* tissue; but the growing point of a root is not at its absolute extremity, which is covered by a cap-shaped or hood-like portion of epidermis of its own, continuous likewise behind with the cambial structure. This cap-like sheath of the point of the root may be compared with the head of an arrow, forming a firm body, which can be pushed forward by the growing force behind, to penetrate through the resisting soil. This cap is subject to destruction and decomposition by external agencies, and is less distinctly seen in roots growing in earth than in those of aquatic plants. In all cases it is constantly undergoing renewal by cell-development at the back part; and when it remains undissolved, as in many water-plants, it becomes very large; when it undergoes decomposition in proportion as it is renewed behind, it presents an irregular, ragged appearance, which probably gave rise to the idea of a spongy structure at the end of the rootlets.

"In some roots the epidermis produces no *fibrils*, but remains smooth. This is especially the case in the delicate filamentous roots, annually thrown off, of many Monocotyledons, as of the onion, hyacinth, crocus, &c. In these roots the epidermal cells retain their general delicate character throughout their existence; and probably the roots of this character absorb by their surface throughout their whole length; while in woody roots the absorbent action is confined to the rootlets—to the regions near the growing points,—where the epidermis is still delicate and covered with its hair-like fibrils.

"In woody roots, as the whole organ increases in size and the internal part becomes lignified, the cortical region changes its character. The epidermis dries up, and its place is taken by a corky structure, formed of two or three layers of the cells previously subjacent to the epidermis. When this change has taken place, the direct absorbent power may be regarded as lost. Simultaneously with this change, the inner cortical parenchyma often increases considerably in quantity, and this is particularly the case in fleshy roots, where this region subsequently becomes the reservoir of accumulated nourishment.

"The centre of a very young root is occupied by a cord of cellular tissue of different form from the cortical parenchyma, consisting of elongated cells—the *cambium* of the future wood, which merges, near the growing point, in the focus of cell-development lying just behind the apex of the rootlet, where the nascent cells are all alike. The central cord very soon displays traces of the structures called ducts, and the cells assume the form, and more or less the substance, of the wood-cells of the stem. Some important differences exist as to the arrangement of their constituents in different classes of plants. In Dicotyledons (such plants as turnips, beans, pease, our native timber-trees, &c.), the structure of the central or woody part of the root differs from that of the stem chiefly in the absence of a central pith, together with the circumstance that the so-called vascular structure consists of short-jointed ducts, without the more flexible spiral vessels.

"In ordinary Dicotyledonous roots, when no tuberous development occurs, the central woody structure soon acquires its distinctive character. The wood of the stem consists originally of a number of perpendicularly arranged cords, standing in a circle around the pith, a certain number of which pass out into each leaf to form the skeleton of those organs. The lower portions, inside the stem, extend down for a variable distance in different plants. Those of the lower joints of the stem run down into the roots to form its wood; so that here also we find the woody axis at first in the form of distinct bundles, separated from each other by cellular tissue (*medullary rays*), but crowded closely together in the centre, so that there is no pith. In the young root we find the bundles belonging to the cotyledons largest, between these the bundles belonging to a number of successive leaves. As the stem has its leaves developed, the number of these bundles is increased, until at length a complete circle is formed. When the stem has its joints elongated, the number of bundles extending down into the root is apparently more restricted than when the root is crowned by a tuft of leaves. The bundles belonging to the leaves, formed at a certain height from the root, have their origin at the points where some of the lower ones run out into the leaves, so that they take the place of the latter in the circle surrounding the pith.

"When the root is not tuberous, the woody bundles grow by the conversion of their cambial tissue into wood and ducts, and soon form a solid mass of wood, the wedge-shaped parts of which are more or less distinguishable in different cases. Sometimes the medullary rays separating them remain tolerably large; in other cases these are lost sight of, and the separate bundles are then often only roughly traceable by the arrangement of their larger ducts.

"The woody axis thus formed exhibits at its outer surface (next the rind) a *cambium*-region, where new development of wood takes place, as in the stem, in perennial plants forming annual rings, and where the buds giving rise to branches originate. But when we proceed outwards from here, we miss the next constituent of the stem, namely the *liber*, or bast fibres, which are absent from the root, ending at the 'collar' or point of junction of the root and stem. On the other hand, the cellular structure of the rind or bark is mostly very much developed, and is renewed on the inside by the cambium-region, in proportion as its outer parts are destroyed. The outer part of the rind of oldish roots exhibits a corky texture; and in the roots of trees this rind acquires great solidity, forming a kind of false corky bark if the roots are exposed.

"Where the roots of Dicotyledons become tuberous, very different departures from the regular structure are met with in different plants,—for example, in the turnip and its allies, the carrot, parsnip, &c., and the beet or mangel-wurzel. In the first group the unnatural production of succulent cellular tissue takes place in the medullary rays which invade and break up the woody bundles, and scatter their elements so that they are found distributed in irregular radiating rows in a great mass of parenchymatous tissue. This tissue is by no means a continuation of the pith of the stem, although it bears some resemblance to it. There is a distinct boundary of wood where the root joins the stem. This is probably of importance as regards the 'keeping' qualities of the roots. In the carrot there is a similar development in the woody region, but not so marked; while an equal, if not greater, production of parenchyma takes place on the outer side of the cambium, forming a thick fleshy rind. A thickened rind of this kind is found in most of the fleshy fibrous roots of perennial herbaceous Dicotyledons, such as groundsel, primrose, &c.

"In the beet, the structure both of the stem and root is unlike that of ordinary Dicotyledons; and the changes produced by cultivation cannot be discussed here.

"The roots of Monocotyledonous plants, such as those of grasses, onions, ordinary bulbous plants, &c., are temporary structures, thrown off year after year, or dying with the stem in annuals. Their woody structure differs very much from that of the roots of Dicotyledons, so that they are easily known by observing a cross section; but the cortical region and the growing extremities differ little in the roots of the two classes. The principal characteristic of the roots of the Monocotyledons lies in their woody central cord exhibiting no trace of distinct bundles separated by medullary rays, but consisting of a central column of wood, with its 'ducts' or vascular structures lying on the outside, at the region where the wood adjoins the cortical parenchyma. A kind of *cambium* exists here also, although no annual rings are ever formed, since it is at this outer surface of the woody region that the root-buds originate.

"The structure of the ordinary roots of herbaceous Monocotyledonous plants may be well examined in the onion. If we place an onion bulb over water in a long glass, like a hyacinth-glass, it soon sends out a number of slender blunt-ended roots, of white colour, the tips only having a yellowish tinge. By placing longitudinal sections of one of them under the microscope, we can trace the mode of development of their roots. The extreme point is clothed by irregularly formed cells, loosely coherent, and evidently being partly thrown off by expansion of the structure beneath; these cells pass laterally into a stratum of elongated cells, which clothe the whole external surface of the rootlet. In the interior of the conical end of the root we find a mass of nascent cells, with their walls scarcely distinguishable, in a state of rapid multiplication by division: this is the chief focus of development of the root. Continuing the examination upward to the older part of the root, the rudimentary cells are soon found arranged in rows parallel to the direction of the root: at first they are very short, then squarish in the side view;

and by degrees they are elongated, until their length is much greater than their breadth; they also expand laterally to a certain extent after their first formation; but this growth ceases, so that the rootlet has a fixed diameter. The cell-division seems to be repeated in these cells in the direction of their length after they have attained their full diameter. While young, near the tip of the root, they are densely filled with protoplasmic substances; as they expand they appear clearer, and contain only a moderate quantity of protoplasm, with abundant watery cell-sap. The rudimentary cells developed in the very centre of the point of growth become cells of much less diameter and more elongated form, and constitute the rudiment of a fibro-vascular cord running through the centre of the rootlet; at a little distance from the point, traces of spiral markings may be detected on the walls of some of these cells, which are becoming *vessels*,—the distinguishing marks of the fibro-vascular bundles. Higher up in the root, the central fibro-vascular cord is clearly recognizable, surrounded by parenchymatous cells, themselves enclosed by a continuous layer of delicate epidermal cells. In these roots the epidermal cells do not grow out in hairs (radical fibrils).

"Roots of this kind show very clearly that the elongation of roots takes place by increase at the point only. This is seen by noticing the relative dimensions of the cells in the different parts; but it may be proved still more evidently by marking the roots, when of some length, at equal distances, with touches of Indian ink. When we watch the further growth of a root thus marked, we see that the spots on the upper part of the root do not become removed to a greater distance from each other, but new structure is added on below the marked parts. The same important law of growth is illustrated by the natural marks made by branches arising from the roots, which remain permanently at their original distance apart, as may be clearly seen in the transverse streaks on the surface of the root of a carrot."

XX.—*Additional Gleanings in British Conchology.*

By J. Gwyn Jeffreys, Esq., F.R.S.

In continuation of my notices on this subject, I have only occasion to make a preliminary remark, that, although I have at present no new species to describe, the communication of any facts which may serve to increase our knowledge of already known species is not less valuable or interesting than the publication of novelties.

Acephala Lamellibranchiata.

Teredo megotara, *Forbes and Hanl. Brit. Moll.* vol. i. p. 77.